CATALYTIC SEPARATOR PLATE REACTOR AND METHOD OF CATALYTIC REFORMING OF FUEL TO HYDROGEN

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation-in-part of U.S. Application No. 09/737,268, filed December 13, 2000, which claims the benefit of U.S. Provisional Application No. 60/238,867, filed October 6, 2000.

TECHNICAL FIELD

[0002] The invention relates to plate or channel-type reactors using integrated bicatalytic heat transfer separator walls, each wall surface containing or having coated thereon a selected catalyst. The reactor provides for continuous and simultaneous reaction of two different process reaction streams in the channels defined between the walls, wherein a first process reaction stream undergoes high temperature exothermic reaction in a first channel and a second process reaction stream undergoes an endothermic heat-consuming reaction in a second channel separated from the first by the heat transfer separator wall. The heat produced by catalytic oxidation of fuel in the first channel is transferred to the second channel where a catalytic reforming reaction takes place. Multiple modular catalyst coated separator wall units or cells may be stacked to provide a reactor of any desired throughput capacity and portability. This invention also comprises methods for the catalytic reforming of hydrocarbon fuels for the production of synthesis gas or hydrogen employing the bicatalytic reactor of the invention.

BACKGROUND ART

[0003] The steam reforming of hydrocarbon fuels for the production of synthesis gas or hydrogen is a well-established technology. A common process is steam reforming, where a suitable reforming catalyst facilitates the reaction between the hydrocarbon feed and steam to generate carbon monoxide and hydrogen. Conventional steam reformers consist of a reforming section containing the catalyst and a burner to supply heat for the endothermic reforming reaction. Steam and a hydrocarbon fuel are supplied to the reforming section, and the product hydrogen must be separated from the carbon monoxide.

[0004] A typical industrial reformer contains multiple tubes made of refractory alloys. The tube interiors constitute the reaction zone and they are packed with porous pellets of material impregnated with a suitable reforming catalyst. The tube diameter varies between 9 and 16 cm and the heated length of the tube is normally between 6 and 12 meters. The tubes are mounted in a furnace with burners that heat the reaction zone to a temperature that is typically as high as 1300 °C in order to insure that the temperature of the catalyst in the tubes is around 700 °C. The burner operates at temperatures considerably higher than the temperatures required by the reforming reaction because the combustion gases must transfer the heat of reaction through the reactor wall to the reforming gases and to the catalyst pellets in which the reaction takes place. High burner temperatures are necessary in order to insure that the reforming catalyst operates at the desired temperatures. One undesired consequence of those high burner temperatures is the production of NO_x in the combustion flue gases. In addition, because a gaseous stream transfers the heat of reaction, the volume of the furnace is necessarily large.

[0005] Equally important, such industrial reformers can not be scaled to smaller sizes for modular portable units in order to provide sufficient hydrogen-rich gas for fuel cells or chemical reaction processes. For example, modular portable fuel cells

are envisioned for residential and small business electrical production and water treatment using fuel cells, and they are of particular interest in remote and arid areas and in undeveloped countries, which lack a power grid, technological capability, and the funds for an electricity distribution infrastructure. Another area of interest is for transportation power, particularly for vehicle fuel cells for hybrid vehicle power trains, for mass transit vehicles and trucks. Because of the safety and volume constraints, high purity hydrogen in pressurized tanks is presently not desirable for vehicle fuel cells. Accordingly, the current best solution is to use liquid hydrocarbons, such as LNG, condensed methane, or liquid volatile fuels, such as alcohols or motor grade gasoline, kerosene, benzene, or the like in order to feed an on-board reformer and produce a hydrogen-rich effluent as feedstock for such fuel cells.

[0006] To solve those problems, plate-type reformers, which are compact in size, and within which catalytic combustion at low temperatures is possible, have been proposed. An example of such plate reformers is described in US Pat. No. 5,015,444 of Koga et al. The reformer described therein has alternating flat gap spaces for a fuel/steam mixture and a fuel/air mixture. The combustion gap spaces are filled with a combustion catalyst, while the reforming gap spaces are filled with a reforming catalyst. The catalytic combustion of the fuel/air stream provides the required heat for the reforming of the fuel/steam mixture stream at temperatures substantially lower than 1300°C.

[0007] US Patent No. 5,167,865 of Igarashi et al describes a more compact embodiment of the plate reactor. Igarashi et al proposed a rectangular wall reactor consisting of alternating stages comprising a heated reformer area separated from a conductive heating area. Each stage comprises a plurality of plates, e.g. three plates, a pair of spaced boundary plates and a center partition plate, the spaces between the partition and boundary plates being respectively the heated reformer area and the